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ABSTRACT

This paper addresses the role of science education in today's society and the objectives of instruction in science. Observing that science cannot solve all of the problems of the world, and that science education has had little effect on the willingness of the general public to accept superstitions, the author argues that instructional approaches to the testing of hypotheses must be re-examined. After briefly reviewing the development of general educational goals during the past century, the author turns to the objectives of science education. He discusses knowledge objectives and identifies four issues related to propositional knowledge. Turning to the debate over emphasis on mastery of conceptual schemes vs. understanding of scientific processes, he discusses normative and cognitive objectives. In conclusion, he raises the question of when the objectives of science education should be stated in behavioral terms or formulated more generally. (SD)

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ISSUES IN SCIENCE EDUCATION: CHANGING PURPOSES OF SCIENCE EDUCATION

Stan Williamson

I. Introduction

Changing world events, and conditions of life on this planet, reveal that science educators must take a new look at the general purposes (objectives) of science education, and that new perspectives for teaching science be developed. Changes take place so rapidly that one of the crucial issues in society today is to determine how man may become more in tune with a science-dominated and a science-conditioned world. In other words, "Man must learn to come to terms with nature, to live with it, to understand it, and to control it." (Krusch p. 20)

Few of us would deny that a revolution has occured in science education during the past twenty years--some elements of the revolution very positive and good, other elements quite negative. This revolution was brought about by special needs of society--a need for scientific literacy if participants in that society are to make maximum contributions, and the need for specialists--scientists and engineers. Efforts to meet these needs resulted in the development of new curriculum materials in all sciences, the

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identification of more precise objectives of education and science education, and in expanding research in learning theory. The contributions of Ausubel, Bruner, Gagne, Piaget and Skinner have had considerable influence on the present direction of science education, particularly: in identifying the science content of greatest worth to students at various age levels; in providing models for stating objectives and in revealing how learning takes place.

Regardless of the efforts that have been made in the past two decades to identify objectives and content, we enter the last quarter of this century with many unanswered questions, unsolved problems, and unresolved issues. Like the political issues in society today, issues in science education appear to be fragmented, vague, unclear and so complex that it is difficult to really get a good grasp on them.

Education in general, and science education in particular, has been subjected to severe criticism by the lay public, and by specialists in various fields. For example, individuals with some expertise in philosophical analysis have been critical of

the many ambiguities that exist in the terminology in science education. Martin (5), has analyzed the logical structure of such terms as (a) scientific inquiry, (b) explanation, (c) definition, and (d) observation and clearly reveals the confusion that prevails in terminology in common usage in the field. Philosophy of science and/or philosophical analysis properly applied would assist science educators in their thinking about science, how they view the curriculum and how they employ other educational practices.

During the next 15-20 minutes I want to explore with you some of the crucial issues related to the objectives of science education. To set the stage for such a presentation it will be helpful, for me at least, to briefly review and discuss (1) some of the limitations of science, and (2) the general aims of education today. Hopefully, this background material will relate solidly with issues pertinent to the objectives of science education and should give some indication of the direction science education should take in the future. I'll give it a try.

II. Some limitations of science

Science and technology, together, have played an extremely

important role in the evolutionary development of Western culture. Through the years science has provided man the means of resolving many of his pressing problems. Krusch says "it has all but banished the need for superstition and the blind acceptance of dogma, it has taught man that the Universe is ordered and has revealed the elements of that order, it has, with technology, shown man how to improve his physical conditions of life, and has greatly enlarged the dimensions of man's world through travel and communication." We have every reason to believe that science will continue to serve man in liberating his mind and spirit.

He further reminds us that though science has removed the need for superstition and the life of extreme hardship, both superstition and hardship persist in the lives of a large percentage of the inhabitants of this earth. For others, science "has in their minds and emotions become the object of the same mystical reverence that the priesthood of an earlier era enjoyed--it is believed to be the source of all wisdom and truth to which access is so difficult, the rights of initiation so arduous, that access must be denied except to a few of the elect."

Mendelsohn[6] alluded to the same thing in his 1975 NSTA Convention SUNOCO Science Seminar when he suggested that "(1) the arrogance of contemporary science must be replaced with modesty. (2) accessibility is a must for science--allow people in, demystify the knowledge we're dealing with, using language understood by the general public, (3) science must be reconstructed to be non-violent, non-coercive and non-manipulative, and (4) science must be in harmony with nature.

One may conclude, that the increased emphasis of science teaching since the turn of the century has produced only minimal changes in the public's acceptance of superstitions and un-founded beliefs on a large segment of society. In fact there is evidence that a pseudo-science has emerged, complete with a systematic body of propositions, practices and attitudes that give the appearance of being true science. The continued popularity of Astrology, and the many and varied T.V. commercials with their un-scientific claims reveal the gullability of the general public. It may well be that students studying science, in many instances, have not been given the opportunity to master the art of hypotheses testing by

refutation as well as by confirmation to give the depth of understanding needed for decision-making in a modern world.

There appears to be some evidence, at least, that science students have not understood, accepted or appreciated the basic limitations of science. It seems to me that greater efforts should be made in content selection and in the identification of objectives to reveal to the student that

(1) The fields of science cannot guarantee to produce any special desired result. Such as--providing an adequate food supply to feed the ever-increasing world population--or water, or health. Some things are finite. There are some things that science (as we know it) cannot do or ever hope to do.

(2) Science, in itself, because of its intrinsic nature, cannot make moral judgments. Only man can do that.

It appears to me that greater attention must be given in science teaching to the important limitations of science. One possible way to incorporate this in a science program would be to modify proceedures used in hypothesis testing. The issue could then be stated as:

ISSUE 1. Shall hypothesis generation and testing be based on the confirmation approach, the refutation approach or a combination of various approaches?

III. Importance of the General Aims (objectives) of Education

Traditionally the airms of education (Comenius, Rousseau, Pestalozzi, Herbart and Froebel--as examples) placed major emphasis on "preservation of natural goodness, and virtue, and the form of society which is in harmony with them"(1) The relative importance of the attitudinal or affective domain, as viewed by these philosophers is quite evident.

Dewey expanded on this concept and introduced many new dimensions in his writings on educational philosophy. While he never stated specific aims of education, as such, he did allude to them on numerous occasions: "The aim of education is to be found in the process itself, and not as a final goal to be reached. Education proceeds by constantly remaking experience, and it is this reconstruction which constitutes its value and accomplishes its aim. . . . Hence education means the enterprise of supplying the conditions which insure growth, or adequacy of life, irrespective of age. . . .

The primary root of all educational activity is in the instinctive, impulsive attitudes and activities of the child, and not in the presentation and application of external material." (Eby & Arrowood, p. 866-69).

In 1918 the Commission on the Reorganization of Secondary Education proposed a set of seven cardinal objectives (health, command of fundamental processes, worthy home membership, vocational competence, effective citizenship, worthy use of leisure, and ethical character) of education. Twenty years later (1938) the Educational Policies Commission developed objectives of education under four major headings: self realization, human relationships, economic efficiency and civic responsibility.

Each generation seeks to further identify and define the major aims of educati --authors change, words are reorganized and regrouped, but the general meaning remains much the same. Changing conditions in society are reflected in any statement of aims of education--its problems, its pressures, and its needs at that immediate time. Piaget (p. 231) seems to have captured the needs of society in his statement on the aims of education

which are stated in clear and concise terms as follows:

> The goals of education are: . . . to create men who are capable of doing new things, not simply of repeating what other generations have done--men who are creative, inventive, and discoverers. The second goal of education is to form minds which can be critical, can verify, and not accept everything they are offered. . . So we need pupils who are active. . . who learn early to tell what is verifiable and not what is simply the first idea to come to them. . . (6. p 231)

I'm sure we are in whole or partial agreement with Piaget's statement of aims for the need to develop creative and scientifically literate individuals equipped with the tools necessary to perform satisfactorily in the decision-making process, if they are to adjust to, and live in, a modern complex world. The key to achieving such goals lies in the proper selection of content and in selecting appropriate teaching strategies. One may question whether current science curriculum materials, as used in the normal classroom, achieve the goals of education suggested by Piaget. Much work remains to be done in this area.

In final analysis, the objectives of science education must grow out of, and be responsive to the accepted societal goals of education. Changes in society occur rapidly and irregularly, giving education little lead time to adjust to, and meet, the requirements of new situations. Specialists from various areas of study--sociologists, historians, psychologists and philosophers must join professional educators in identifying and defining the major goals of education. They would contribute by providing a degree of authority and inspiration in a period of rapid social change and scientific advancement.

IV. The Objectives of Science Education

Just as the aims of education have changed and have been in a state of ferment throughout the history of American education, so have the objectives of science education since becoming a part of the school curriculum. During the past two decades the major concerns have centered around (1) structure and conceptual schemes of science deemed of value to students, and (2) the processes of science which students were to understand and use in solving everyday problems. Debates involving educational theorists

have developed over the relative place and importance of structure and process in the science curriculum resulting in rethinking the traditional objectives of science education--scientific knowledge, understandings, skills, and behavioral modifications.

A. Objectives related to knowledge

Traditionally, the acquisition of knowledge, has been considered the first and the major goal of science teaching. It is still considered important, and in the mid-seventies we are still seeking an answer to the question: What knowledge is of most worth?--for all individuals living at this time in history, in this social setting, and in this ever-changing technological society. Historically, scientific knowledge to be acquired consisted basically of the scientific facts, concepts, principles and theories used by scientists, while more recent emphasis has been on the general nature and structure of science and the processes of scientific inquiry.

Martin[5] suggests that knowledge to be acquired has basically been propositional knowledge and represents it schematically as:

1. x knows that p
2. p is true
3. x is justified in believing that p
4. x believes that p^2 (knows sodium burns yellow, but does not believe it

Propositional knowledge is important in any study of science but to be effective it must satisfy each of four prescribed conditions. All too frequently, in acquiring knowledge students are not required to justify why they believe p. Teachers are satisfied with the first two conditions--x knows that p and believes that p is true, thereby able to respond correctly on tests or other evaluative materials. Martin suggests two kinds of justifications are needed (1) those that are extrinsic to the subject discussed--because the textbook or teacher says so; and (2) those intrinsic to the subject matter--investigators have burned sodium salts and they always burn yellow. Again students may be given the opportunity to confirm or refute propositional knowledge in the classroom and in the laboratory. A major problem for curriculum designers and teachers is to know when to use justifications that are extrinsic and/or intrinsic to the subject matter--at what age level, at what age? Propositional knowledge that utilizes only the first two conditions cannot, and will not, prepare students for decision-making responsibilities in a complex technological world. It is not the mere acquisition of knowledge per/sec that is important but rather achieving

scient fic understanding of the World about us.

The issue may be stated as:

ISSUE 2. Shall the central purpose of science education be the acquisition of propositional knowledge extrinsic and/or intrinsic or shall emphasis be on science as a dynamic enterprise, its conceptual schemes and processes?

Another major debate has developed as to whether emphasis in science teaching should be on structure and conceptual schemes which all students should study and master or on the processes of science which students are to understand and use. In this debate the place of inquiry in teaching science becomes a focal point. Schwab identifies the objective of the inquiring classroom as one in which learning in science is "not only the clarification and inculcation of a body of knowledge, but the encouragement and guidance of a process of discovery on the part of the student" (Schwab, p. 66). At the other end of the spectrum Ausubel contends that there are recognizable specific areas of knowledge that are basic in the study of science (broad ideas) which should be taught to, and learned by, students.

Shulman and Tamic in a Chapter on Research on Teaching in The Natural Sciences (p. 1105) found in the Second Handbook on Teaching suggest that controversies in stating objectives in science education be grouped into two levels of disagreement with respect to subject matter: the normative (what students ought to know); and the cognitive (what learnings can best be retained).

A. Normative level objectives.

Objectives at this level attempt to identify the specific science domain that students should learn and understand--the essentials. They attempt to bring about satisfactory answers to "age old" questions: What is science? What is the role of the scientist? What scientific knowledge is most beneficial to the student? How curriculum makers, and classroom teachers answer these questions will determine the nature of the objectives, subject matter emphasis, and teaching strategies used. There are many issues and sub-issues that may be identified at this level with the center of focus on how students can come to know and understand the natural world as viewed by science and at the same

time appreciate the work and research efforts of the scientist. Is this what science education and science teaching is, or should be all about?

B. Objectives at the cognitive level.

Objectives at the cognitive level attempt to identify knowledge in science that is learnable, transferable, and of basic value to the learner. The debate among educational theorists focuses on the place and importance of transfer and specifically on what is transfered in the learning process (Shulman and Tamir, p. 1107). For example Bruner stresses lateral transfer of broad principles of science from topic to topic, and from field to field. He also believes that the transfer of the knowledge getting process of greater importance than the acquisition of knowledge. Gagne emphasizes the importance of vertical transfer and brings it about through learning hierarchies. He makes a clear distinction between verbalized knowledge and intellectual skills or strategies. Ausubel supports the thesis that only subject matter knowledge is transferred. It is quite evident from the literature, from curriculum materials developed that the resolution of issues at the

cognitive level are not in sight at this time--much research is needed.

A major issue regarding the relative importance of objectives at the normative level and cognitive level may be stated as:

Issue 3. Shall the major objectives in science education be centered around knowing--the identification of a body of knowledge to be learned per sec or the modes of knowing science that are both useful and permanent?

Another major area of debate in science education today relates to the basic techniques in writing objectives. The controversies focus on the general question--How specific must objectives be stated to provide guidance needed by curriculum planners, teachers, and students? The work of Tyler (1950), Bloom (1956) and Mager (1962) on writing of objectives has influenced committees preparing new science curriculum materials and teachers using those materials in the classroom. Mager (p. 11-12) believes that objectives should be specific rather than general, that they should state in specific terms: what we want the student to know, and what the learner will be doing--in other words describe the desired behavior of the

learner. As you know, to accomplish this task he has suggested these steps:

1. Identify terminal behavior by name--evidence learner has achieved objective.
2. Define the desired behavior--condition under which behavior will occur
3. Specify criteria of acceptable performance.

This programmed instruction approach has influenced educational programs at the local district level, and in programs proposed by State Departments of Education. Performance based and/or Competency Based education has become the "battle cry" of education today. Curriculum planners and classroom teachers may be spending an inordinate amount of time writing behavioral objectives which to-date, at least, do not have ample research evidence to support. A critical question is: will the creative, innovative teacher be restricted by behavioral objectives with a high degree of specificity, preciseness, and prescription?

Issue 4. Shall objectives in science education be stated behaviorally with specific performances, conditions, and criteria for judging performance, or should they be stated more generally with fewer restrictions on the teacher and student?

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